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PREDICTION OF HERBAGE YIELDS OF TALL BLUEBELL AND WHITE POLEMONIUM FROM HEIGHT OF AND NUMBER OF STEMS

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ABSTRACT

Presents regression equations for predicting herbage yields of tall bluebell (Mertensia arizonica *var.* leonardi) *and white polemonium* (Polemonium foliosissimum) *using the interaction of height x number of stems. Equations are intended to serve as a guide for future studies, and not for use as predictive purposes generally, or for other species.*

In studies where individual plants are observed over several years, a method of assessing growth or production must be used that does not damage the plant and possibly influence future observations. A measurement of the total yearly production of herbaceous plants often is desired, but this is difficult to obtain accurately without clipping the plants. Visual estimates of weight can be made, but such a technique requires considerable training.

Methods of predicting yields, mainly of grasses, from easily measured plant characteristics, such as leaf or culm height, basal area, and number of culms, were summarized by Wright.[2] At the same time, he reported that individual plant weights of two bunchgrasses, *Stipa comata* and *Sitanion hystrix*, could be predicted accurately from the number of culms, leaf length, and the interaction between these two characteristics.

Study Procedures

The study was conducted in two forb-dominated openings in aspen rangeland at 8,300 feet elevation on the Uinta National Forest, Wasatch County, Utah. The annual precipitation for the area, based on short-term records, ranges between 27 and 39 inches, about 75 percent of which occurs as snow from October through May. Soils are about 5 feet deep with well developed silt loam A horizons.

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[2]Henry A. Wright. Predicting yields of two bunchgrass species. Crop Sci. 10: 232-235, illus. 1970.

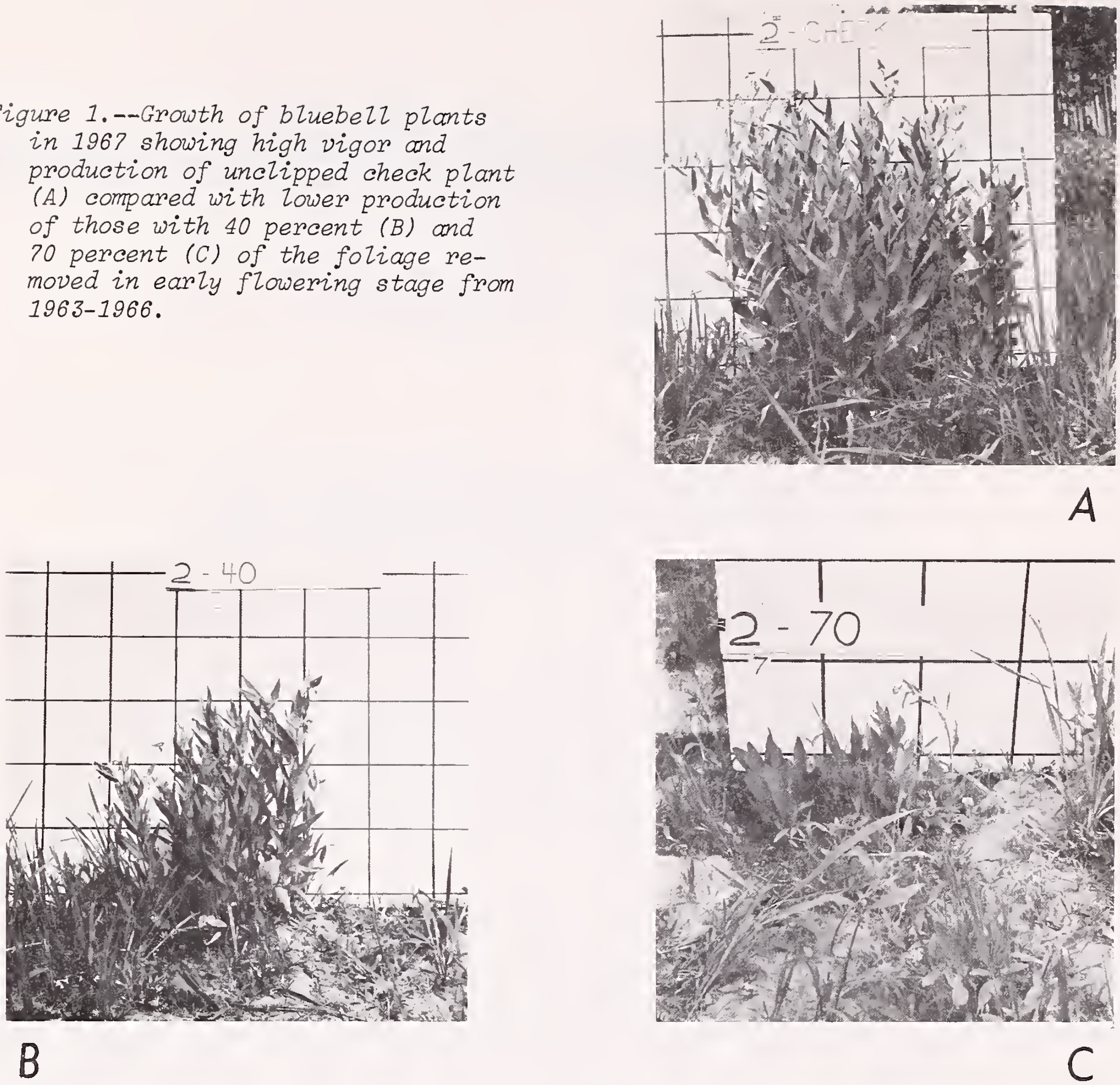

Figure 1.--Growth of bluebell plants in 1967 showing high vigor and production of unclipped check plant (A) compared with lower production of those with 40 percent (B) and 70 percent (C) of the foliage removed in early flowering stage from 1963-1966.

The species studied were tall bluebell (*Mertensia arizonica* var. *leonardi*) and white polemonium (*Polemonium foliosissimum*). Both are nonrhizomatous species in which a closely spaced cluster of flowering stems constitutes an easily identifiable plant. The plants were harvested in July 1967 at the termination of a clipping study in which the effects of time and intensity of foliage removal on production were reported.[3]

Fifty-two bluebell plants from the two sites were evaluated. Twelve were check plants that had not been clipped; the rest had been clipped at various levels for 4 consecutive years, 1963-1966. Nineteen polemonium plants from only one of the two sites were studied, six of which were unclipped check plants.

Depending upon the severity of the foliage removal, the clipped plants were lower in production and had fewer, shorter stems than the unclipped check plants (fig. 1). Plants that were so low in vigor that they produced only basal leaves and no definite stems were excluded.

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[3]W. A. Laycock and P. W. Conrad. How time and intensity of clipping affect tall bluebell. J. Range Manage. 22: 299-303. 1969.

In late July 1967, after the plants had attained full growth, the number of stems was counted and the average stem height was measured for each plant. For bluebell, the height of the third tallest stem was also measured to get the average stem height. There are usually one or two stems longer than the rest and the third tallest stem could be measured easier and more accurately in the field. Polemonium has fewer stems than bluebell and the average height can be determined easily. After these stems were counted and measured, the plants were cut at ground level and the green and ovendry weights were determined.

Data for each species were analyzed by stepwise multiple regression using ovendry weight as the dependent variable, while the number of stems, the average or third tallest stem height, and the linear interaction of these (height x number) were used as independent variables.

RESULTS

For both species, the simple interaction between stem height and number accounted for more than 90 percent of the variance in dry weight. For bluebell, the coefficient of determination (R^2) for the simple linear regression between weight and this interaction was 0.92. The addition of number and height of stems as independent variables only increased the value to 0.94. For polemonium, the coefficient of determination was 0.97 for the simple regression using the interaction variable and 0.98 when the stem number and height variables were added. For both species, the additional variables resulted in little or no reduction in the standard error.

Figure 2A shows the individual data points for bluebell at both sites. It also shows the regression line and the confidence limits at the 95-percent level for the mean and for individual observations. Initially, the regressions were calculated separately for the two different sites; however, the data were combined because the regression coefficients and formulae were similar:

Site 1: $\hat{Y} = 0.0661X - 22.61$; standard error of the predicted mean = 5.21

Site 2: $\hat{Y} = .0642X - 11.46$; standard error of the predicted mean = 2.98

Combined: $\hat{Y} = .0638X - 14.72$; standard error of the predicted mean = 2.94

where: $\hat{Y}$ = predicted dry weight in grams and X = height of third tallest stem x number of stems.

Figure 2B shows the simple regression between dry weight and the interaction of stem height and number for polemonium. The presence of the three large plants shown by the points in the upper right portion of the figure obviously increased the degree of correlation. To determine the effect on the regression coefficient, the analysis was repeated without these three plants. The coefficient of determination (R^2) was reduced from 0.97 to 0.88 but the regression coefficient and formula remained essentially unchanged:

Original: $\hat{Y} = 0.1328X - 5.94$; standard error of the predicted mean = 1.22

Amended: $\hat{Y} = .1293X - 5.59$; standard error of the predicted mean = 1.02

The coefficients of determination and the confidence intervals are somewhat biased because of the skewed distribution of plants of various sizes in both species. Log transformation of the data resulted in a more normal distribution of plant sizes and lowered the coefficients of determination slightly ($R^2 = 0.90$ for bluebell and $R^2 = 0.94$ for polemonium).

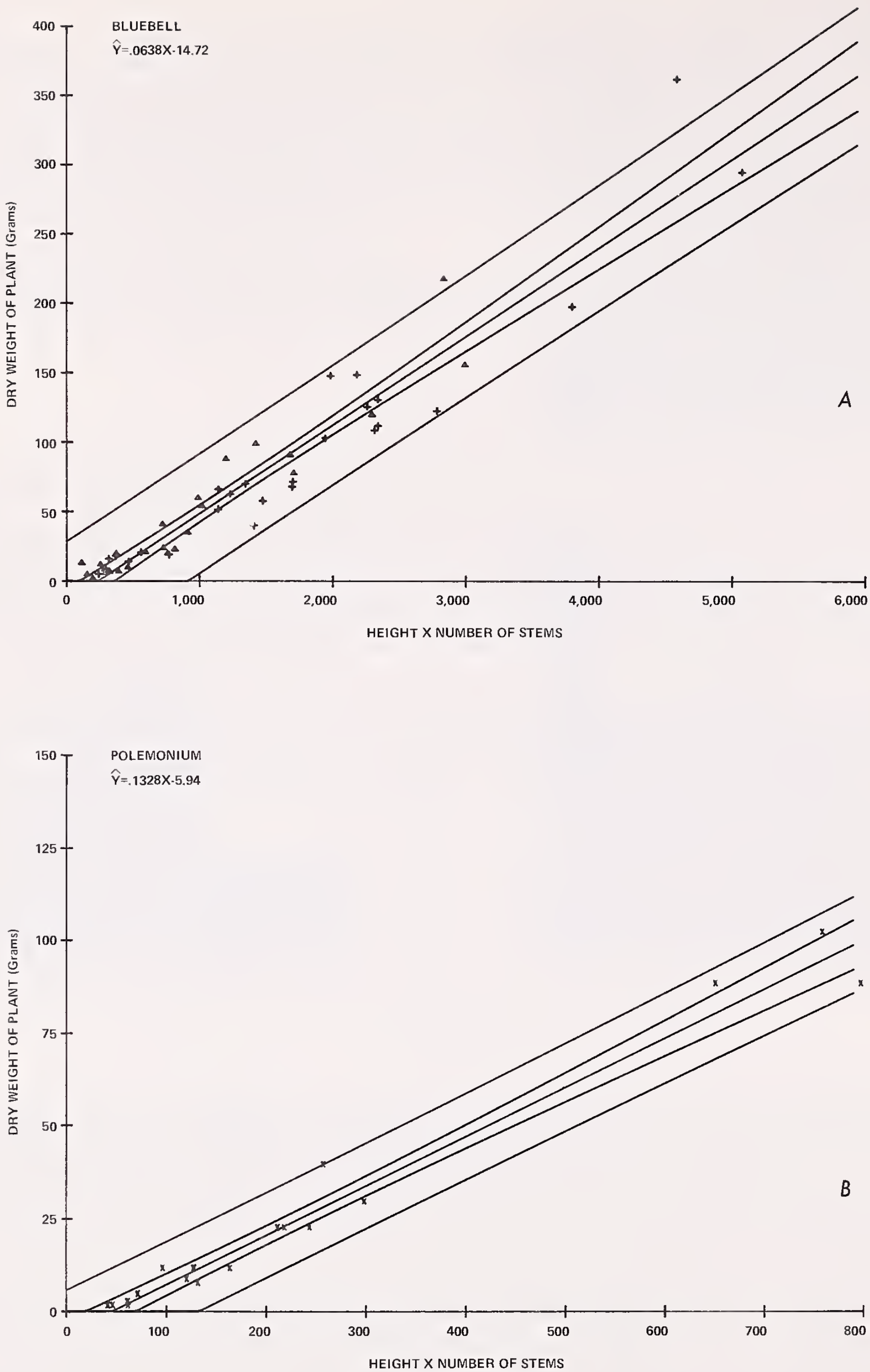


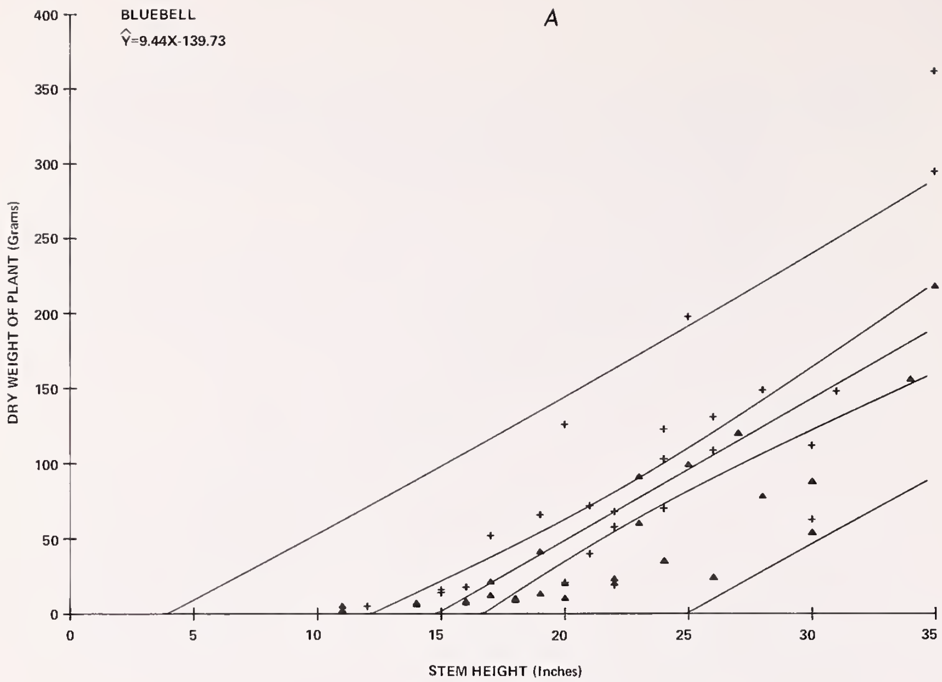
Figure 2.--Relation of plant weight to the linear interaction of stem height and number (height x number) for bluebell (A) and polemonium (B). Confidence limits at the 95-percent level are shown for the mean and for individual observations of plant weight for a given value of height x number.

Table 1.--*Simple correlation (r) between weight and stem height and number for tall bluebell and white polemonium; all are significant at the 99-percent level of probability*

Weight	Stem height	No. of stems	Height x number
		BLUEBELL	
Green	[1]0.81	0.84	0.94
Dry	[1].79	.87	.96
		POLEMONIUM	
Green	[2].76	.96	.99
Dry	[2].76	.97	.99

[1]Height of third tallest stem.
[2]Average height of all stems.

The relationships between height and weight and between number of stems and weight were investigated separately. The simple correlation coefficients were significant well beyond the 99-percent probability level for both species (table 1) but were not as high as the coefficients between weight and the interaction. In spite of the high linear correlation, it appears that the relationship between weight and stem height (fig. 3A), and perhaps between weight and number of stems (fig. 3B), may not be linear. However, further investigation of stem height or number as separate variables in a prediction equation seemed to be unnecessary because the predictive value of the height x number interaction was so great.



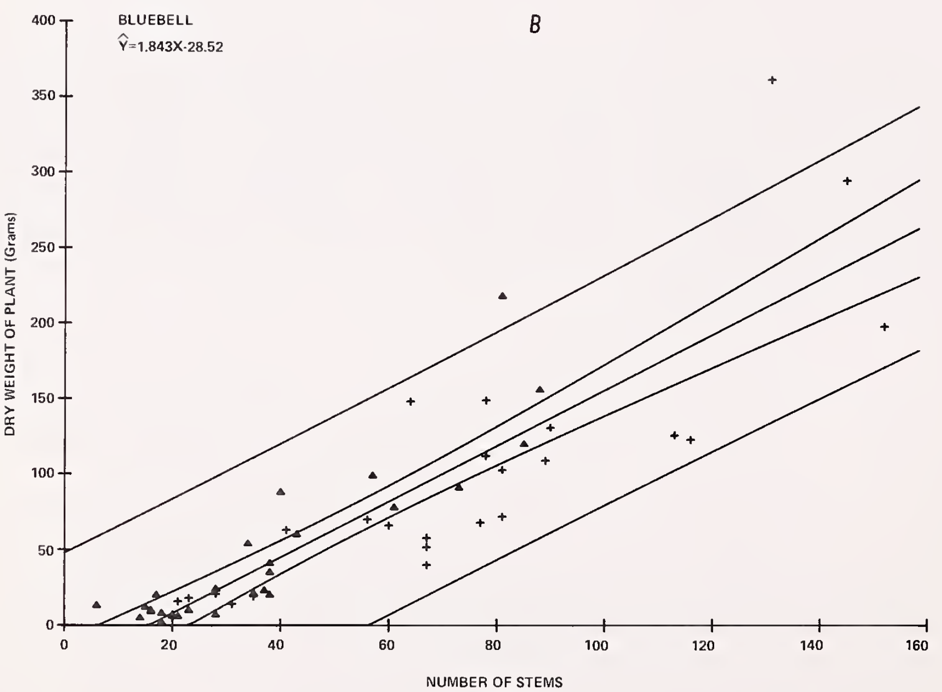


Figure 3.--Relation of plant weight of tall bluebell to stem height (A) and number of stems (B). Confidence limits at the 95-percent level are shown for the mean and for individual observations of plant weight for a given height or stem number.

DISCUSSION

Weights of bluebell and polemonium plants can be predicted with a high degree of accuracy using the interaction of height x number of stems in a regression equation. Weights of other species with similar growth forms undoubtedly could be studied in a similar fashion.

The equations presented in this paper are intended to be used solely as a guide to future research and are not intended to apply to the two species generally, or to other species. However, it is interesting to note that bluebell plants from two different sites yielded similar regression formulae.

Others using these techniques would have to develop predictive equations for the population of plants sampled. If the population consisted of all vigorous, high-producing plants with large numbers of tall stems, the equations would be quite different from those presented here because these were derived from a population of plants with wide ranges in production, height, and number of stems. If distribution of plant sizes were skewed, as in this study, a log or some other transformation might be desirable before attempting regression analyses. In addition, new formulae might have to be developed each year because production of plants differs from year to year as a result of climate. Wright[4] found that regression equations for predicting weight of two species of bunchgrass from numbers of culms and leaf length differed considerably in 2 consecutive years.

Caution must be used in application of such techniques. Even with a correlation as high as I found, the predicted weight of a single plant from its height and number of stems can be quite variable. At the mean value of height x number (1,337) the actual mean weight of a population of bluebell plants will be within 8 percent of the predicted mean (70.7 ± 5.9 grams) 95 percent of the time. However, the actual weight can vary as much as 61 percent from the predicted mean (70.7 ± 43.0 grams) for any one individual plant having the same combination of height and stem number. This means that height must be measured and stem number counted for several plants to get a reasonably accurate predicted weight. The number needed would depend upon the variability of the population sampled.

Use of other plant characteristics to determine weight might have applications in ecological studies beyond that of determining weight of specific plants over a period of years. For example, in autecological studies, growth curves usually are based on increase in height because height can be measured without destroying the plant. If height and number of stems were highly correlated with weight in different stages of growth, growth curves based on increase in dry matter over time would be possible.

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[4]See footnote 2.